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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
STATE GEOLOGICAL SURVEY
FRANK W. DE WOLF, Chief

Cooperative Coal Mining Series
BULLETIN 20

**CARBONIZATION OF ILLINOIS
COALS
IN
INCLINED GAS RETORTS**

BY
F. K. OVITZ
U. S. Bureau of Mines
(Preliminary to an enlarged report by the Bureau of Mines)

ILLINOIS COAL MINING INVESTIGATIONS
Prepared under a cooperative agreement between the Illinois State Geological Survey
Division, the Engineering Experiment Station of the University of Illinois,
and the U. S. Bureau of Mines.



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URBANA, ILLINOIS
1918

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The Forty-seventh General Assembly of the State of Illinois, with a view of conserving the lives of the mine workers and the mineral resources of the State, authorized an investigation of the coal resources and mining practices of Illinois by the Department of Mining Engineering of the University of Illinois and the State Geological Survey Division in cooperation with the United States Bureau of Mines. A cooperative agreement was approved by the Secretary of the Interior and by representatives of the State of Illinois.


The direction of this investigation is vested in the Director of the United States Bureau of Mines, the Chief of the State Geological Survey Division, and the Director, Engineering Experiment Station, University of Illinois, who jointly determined the methods to be employed in the conduct of the work and exercise general editorial supervision over the publication of the results, but each party to the agreement directs the work of its agents in carrying on the investigation thus mutually agreed on.

The reports of the investigation are issued in the form of bulletins, either by the State Geological Survey Division, the Engineering Experiment Station, University of Illinois, or the United States Bureau of Mines. For copies of the bulletins issued by the State Geological Survey Division, address State Geological Survey Division, Urbana, Illinois; for those issued by the Engineering Experiment Station, University of Illinois, address Engineering Experiment Station, Urbana, Illinois; and for those issued by the U. S. Bureau of Mines, address U. S. Bureau of Mines, Washington, D. C.

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FRANK W. DEWOLF, *Chief*

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CARBONIZATION OF ILLINOIS COALS IN INCLINED GAS RETORTS

By F. K. Ovitz

INTRODUCTION

The tests described in this paper were undertaken by the Bureau of Mines as part of cooperative work with the Illinois State Geological Survey Division and the Engineering Experiment Station of the University of Illinois in an endeavor to obtain further information regarding the use of Illinois coals in gas retorts. The results of several tests with Illinois coals by gas companies have been given in a previous report of the Bureau.¹

Under the conditions existing in the winter of 1917-18, it is desirable to use as much as possible of the coal that is mined locally in order that long railroad hauls may be avoided and that the burden now put on the crowded transportation systems of the country may be lightened. Gas manufacturers of the middle west during the past year have seen the importance of a local supply of coal because of the increasing difficulty of obtaining supplies of eastern gas coal, and many companies have considered the possibility of using Illinois coal for at least part of their requirements.

A high yield of gas of good quality is the result sought in the manufacture of illuminating gas in retorts. Coke, tar, and ammonia are by-products that are recovered in order to increase the economy of the process. Coke is the chief of these by-products, and its quality should be given consideration in selecting and carbonizing the coal.

OBJECT OF TESTS

The immediate object of the tests described in this paper was to ascertain how the quality of the coke obtained was affected by mixing Illinois with eastern gas coal. Where Illinois coals have been used for gas making, the usual practice has been to charge a part of the retorts with Illinois coal alone and the rest with an eastern gas coal. The coke from the two coals was kept separate; that from the eastern coals was sold generally for domestic pur-

¹Ovitz, F. K., Coking of Illinois coals: Bull. 138, Bureau of Mines, pp. 54-64, 1917.

poses, while that from the Illinois coal alone was consumed at the plant, usually for bench fuel, as it was not considered as good as that from eastern gas coal.

Another object of the tests was to permit the use of better operating conditions than are possible when the two coals are coked separately. Each coal requires a different temperature or different length of time in the retorts to carbonize it properly, and in practice the maintenance of conditions adapted to give the best results from both coals is difficult if not impossible.

SUMMARY OF RESULTS AND CONCLUSIONS

Illinois coal mixed with Kentucky coal before charging yields better coke than Illinois coal alone. The coke has a more uniform cell structure, is denser, more homogeneous, and stronger.

If all the retorts are charged with the same mixture, uniform operating conditions can be maintained to insure proper carbonization of all the charges. If, however, the coals are used unmixed, the charges of Illinois coal require either a higher temperature or a longer period of carbonization than the charges of Kentucky coal.

Coke from Illinois coal alone contained more ash and had more tendency to form clinker than coke from a mixture of Illinois coal and Kentucky coal. The Kentucky coal had a low ash content, and the ash had a high softening temperature; consequently the ash content of the coke from the mixture was decreased, and the softening temperature of the ash was raised.

The yield of coke from mixtures was larger than from Illinois coal alone, and increased as the percentage of Kentucky coal was increased.

The amount of breeze in the coke made from unmixed Illinois coal was greater than in coke from mixtures. The amount of breeze from mixtures decreased as the amount of Kentucky coal in the mixture was increased.

Mixtures gave higher gas yields and consequently enabled greater production of gas with a given equipment than could be obtained from Illinois coal alone.

There is a considerable supply of Illinois coal with a sulphur content low enough to permit its use for gas making without operating trouble from sulphur.

The more general use of Illinois coal in gas plants deserves careful consideration from gas manufacturers. At many plants in the central west the cost of producing the gas can be consider-

ably reduced by using either Illinois coal alone or by mixing with it another coal.

ACKNOWLEDGMENTS

Thanks are due M. L. Harry, manager of the Decatur Railway and Light Company for extending the use of the gas plant facilities for the tests and for many privileges and courtesies. The author is indebted to John Sieberz, works superintendent of the gas plant, for assistance in the preparations for the test, interest in the work, and help in overcoming difficulties.

Acknowledgments are due F. W. Bedard, gas engineer, and R. B. Richardson, assistant gas engineer, of the Illinois Traction System, and Edward H. Taylor of Chicago for cooperation and advice.

O. P. Hood, chief mechanical engineer of the Bureau of Mines, took an active interest in the work. The chemical analyses and physical tests were made under the direction of A. C. Fieldner, chemist, of the Bureau of Mines.

Credit is due to F. P. Strauch, holder in 1916-1917 of the Illinois Gas Association fellowship at the University of Illinois, who assisted in most of the tests and in compiling the resulting data. The Chicago, Wilmington and Franklin Coal Company donated the car of Franklin County coal that was used in the tests.

DESCRIPTION OF TESTS

Tests of Illinois coal unmixed and of mixtures of Illinois coal with 20 to 80 per cent of Harlan County, Kentucky, coal were made in order to study the effect of mixing on the quality of the coke. The coals used were a part of the regular output of the mines. No attempt was made to maintain any special operating conditions that might suit the Illinois coal, the mixtures being carbonized under the regular plant conditions used with Kentucky coal. Temperatures were measured in the retorts. Samples of the coal and coke were collected and subjected to chemical and physical tests, including the softening temperature of the ash. With the equipment at hand the yield and quality of the gas from the coal mixtures could not be obtained, as the gas from the charges in the test retorts became mixed with gas from the other retorts before purification and metering.

COAL USED

The Illinois coal used in the tests came from three districts as follows: (1) Perry County, bed No. 6, 2-inch lump; (2) Franklin County, bed No. 6, run-of-mine; (3) White County, bed No. 6, run-of-mine. With these a gas coal from Harlan County, Ky., was mixed.

For most of the charges the coals were crushed in a roll crusher set to produce 1½-inch pieces as maximum size. Thirty per cent of the product was smaller than ½-inch size. A few charges were made with smaller sizes in an endeavor to determine the effect of size of coal on the strength of the coke produced; the results were not conclusive because of difficulties in charging these small sizes.

The proximate analyses of the coals used are given in Table 1 following:

Table 1.—*Proximate analyses of coals used*
(As received basis)

Constituent	Perry County, Illinois	Franklin County, Illinois	White County, Illinois	Harlan County, Kentucky
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Moisture.....	10.80	11.74	7.20	4.68
Volatile matter.....	32.81	29.93	35.70	37.06
Fixed carbon.....	47.22	48.52	47.51	53.72
Ash.....	9.17	9.81	9.59	4.54
Sulphur.....	.66	1.39	3.49	.93

RETORTS

The tests were made in the spring of 1917 at the plant of the Decatur Railway and Light Company, Decatur, Illinois, where the carbonizing equipment consists of six full-depth benches of sixes, with inclined sectional silica retorts 15 feet long, 25 inches wide, and 16 inches high, set at an angle of 40° with the floor. Each retort holds a charge of approximately one thousand pounds of coal. The inside top retort in an end bench was selected for the test charges because its use did not interfere with the operation of other retorts. A complete description of the plant is given in the proceedings of the Illinois Gas Association for 1915.¹

¹Richardson, R. B., Inclined retorts: Proc. Illinois Gas Assoc., p. 24, 1915.

MEASUREMENT OF TEMPERATURES

The temperatures inside the retort were measured with a Lunette optical pyrometer, which was compared with a Wanner optical pyrometer. Two observations were made immediately before charging the coal and two immediately after discharging the coke. The temperature was not uniform throughout the retort; usually the hottest part was about one-third of the distance from the bottom end and the coolest part was near the top. The readings were made by sighting the pyrometer alternately on opposite walls near the middle of the retort. The average of all the readings was considered as approximately representing the temperature of the middle part of the retort. During temperature observations the bottom end of the retort was closed to prevent an inrush of cold air lowering the temperature. The top of some charges was not completely carbonized and then smoke and flame from pieces of partly carbonized coal remaining in the retort made satisfactory observations difficult.

MIXING AND SAMPLING COAL

The charges were prepared by making a pile of the number of shovelfuls of Illinois and Kentucky coal required to fill the test retort, and were further mixed by rehandling. For example, if 60 per cent of Illinois coal was required in the mixture, three shovelfuls of Illinois and two of Kentucky coal were alternately thrown on the pile until a charge was obtained. The coal was then shoveled into an elevator that delivered it to one of a number of over-head bins whence it was loaded into the charging buggy and taken to the retorts. That the coals were thoroughly mixed is shown by comparing the calculated percentages of ash with the percentages obtained from analysis of the laboratory samples, as given in Table 2.

Table 2.—*Comparison of calculated percentages of ash in mixtures and percentages obtained from analysis of laboratory samples*

Mixture ^a	Ash from analysis	Calculated ash
	<i>Per cent</i>	<i>Per cent</i>
80 per cent Perry County.....	8.59	8.24
60 per cent Perry County.....	7.71	7.32
50 per cent Perry County.....	6.74	6.85
40 per cent Perry County.....	5.88	6.39
20 per cent Perry County.....	4.83	5.47
80 per cent Franklin County.....	9.08	8.76
60 per cent Franklin County.....	7.80	7.70
40 per cent Franklin County.....	6.77	6.65
20 per cent Franklin County.....	5.54	5.59

^aPercentages of Kentucky coal used equal 100 per cent minus percentages of Illinois coal given.

Samples for analysis were taken by setting aside every tenth shovelful while the coal was being transferred to the elevator, a sample of about 100 pounds representing each charge of approximately 1,000 pounds. Each sample was alternately crushed and reduced by quartering to a sample weighing about three pounds, which was shipped to the laboratory.

WEIGHING THE COAL

The charging buggy was so equipped with hooks that it could be raised by aid of pulley blocks and attached to a steelyard. The weight of the loaded buggy minus the weight of the empty buggy gave the weight of the coal charged.

HANDLING AND SAMPLING COKE

The coke was drawn from the retort directly into a hopper, where it was quenched with water; then it was dumped into a coke car, in which it remained for 12 hours before weighing, in order to allow the water to drain off. It was weighed on the platform scale in daily use at the plant, and immediately afterward was placed on a wooden platform, where it was sampled and the amount of breeze determined as quickly as possible.

The coke was handled with a fork having tines $1\frac{1}{2}$ inches apart. A sample for analysis and physical tests was obtained by throwing every fourth or fifth forkful into a barrel. This barrel when filled was covered and shipped to the Bureau's laboratory at Pittsburgh. A sample, weighing approximately 50 pounds, for moisture determination, was obtained in the same way. The moisture sample was placed in an oven heated to about 38° C. and dried to constant weight. A portion of this partly dried sample was ground to pass a 60-mesh sieve and taken to the laboratory, where the moisture still remaining was determined in an oven heated to 110° C. The sum of these two moisture determinations calculated to the same weight basis gave the total moisture in the coke at the time of weighing, from which the yield of dry coke could be calculated.

The coke remaining on the platform after forking was passed over a one-half inch square-hole screen and the undersize was taken as breeze.

ANALYSES AND PHYSICAL TESTS OF SAMPLES

ANALYSIS OF COAL AND COKE

The samples of coal and coke were analyzed at Pittsburgh by the methods described in Technical Papers 8 and 76.¹

PHYSICAL TESTS OF COKE

The true and apparent specific gravity of the coke were obtained by the methods described in Technical Paper 8.¹ The relative breakage was determined by the shatter test, as described in Tech. Paper 50.² In separating the sizes, the 2-inch screen was shaken until all undersize had passed through.

SOFTENING TEMPERATURE OF COKE ASH

The softening temperature of the ash gives an idea of the liability to form clinkers when the coke is burned. It was determined in a gas-fired furnace, according to the method described in Bulletin 129.³ A reducing atmosphere maintained in the furnace by adjustment of the gas and air supply kept the iron in the ferrous state so that the melting points of the ash were the lowest.

A portion of the completely oxidized ash, ground to pass a 200-mesh sieve, was moistened with a 10 per cent dextrine solution, worked into a plastic mass, and moulded into triangular pyramids each $\frac{3}{4}$ inch high and having a base that measured $\frac{1}{4}$ inch on each side. The pyramids were mounted in a refractory base and after all the moisture was driven off they were ignited in a muffle furnace at a dull red heat to burn the dextrine.

The ignited pyramids were placed in a fire-clay crucible and put in the furnace. Holes in the furnace jacket and the crucible permitted observation, and temperature measurements. The temperature of the furnace was raised gradually to 800° C.; then a rate of increase of not less than 5° nor more than 10° C. a minute was maintained until the cone flattened. Temperature measurements were made (1) at the initial deformation of the pyramid, (2) when the pyramid had fused to a spherical lump, and (3) when the pyramid had melted to a flat layer.

¹Stanton, F. M., and Fieldner, A. C., Methods of analyzing coal and coke: Tech. Paper 8, Bureau of Mines, 42 pages, 1913. Fieldner, A. C., Notes on sampling and analysis of coal, Paper 76, Bureau of Mines, 61 pages, 1914.

²Belden, A. W., Metallurgical coke: Tech. Paper 50, Bureau of Mines, 48 pages, 1913.

³Fieldner, A. C., Hall, A. H., and Field, A. L., The fusibility of coal ash and the determination of the softening temperature, 1917.

RESULTS OF TESTS

The results of tests made with mixtures of Illinois coals, which are the averages of two individual charges, unless otherwise stated, are given in Table 3. In each group the tests are arranged according to the percentage of Illinois coal.

An explanation of the table is given in the following items:

Column 1 shows only the percentage of Illinois coal, the remainder of the mixture being coal from Harlan County, Kentucky.

Column 2 gives the average weight of the coal charged, including moisture.

Column 3, period of carbonization, represents the average time of two test charges.

Column 4, temperature inside of the retorts, represents the average of four readings, taken with the pyrometer sighted on the sides of the retort near the middle.

Column 5 gives the yield of coke as expressed on a basis of dry coke obtained from dry coal. The term "coke" designates the portion of the product from the retorts which was the oversize of a one-half inch square-hole screen.

Column 6 shows the yield of breeze as expressed in percentage of dry breeze obtained from dry coal. The breeze is the undersize of the one-half inch square-hole screen.

In column 19 the percentage of coke substance by volume is computed from the apparent and true specific gravities as follows:

Apparent specific gravity

True specific gravity

$\times 100 = \text{percentage of coke substance.}$ The

percentage of coke substance subtracted from 100 gives the per cent of cell space.

Columns 20 and 21 give the results of the shatter test. In the tests the screen was shaken until all undersize passed through.

In column 22 the softening temperature of the ash from the coke represents the temperature at which the ash collapsed to a spherical lump after being heated at a definite rate.

In column 23 the softening interval of the ash represents the difference between the temperature at which deformation was first observed and the softening temperature.

In column 24 the flowing interval represents the difference between the softening temperature and the temperature at which the cone disappeared, the fused ash forming a flat surface.

DISCUSSION OF TESTS

The coals used in these tests were carbonized under conditions that suited coal from Harlan County, Kentucky. Similar tests with Illinois coal or mixtures of Illinois coal in another type of retort or under conditions more adapted to suit it would lead

to different results. The quality of retort coke depends to a considerable degree upon the temperature of the retorts and time of carbonization, and if these factors were adjusted to better suit Illinois coal, stronger and harder coke could undoubtedly be obtained.

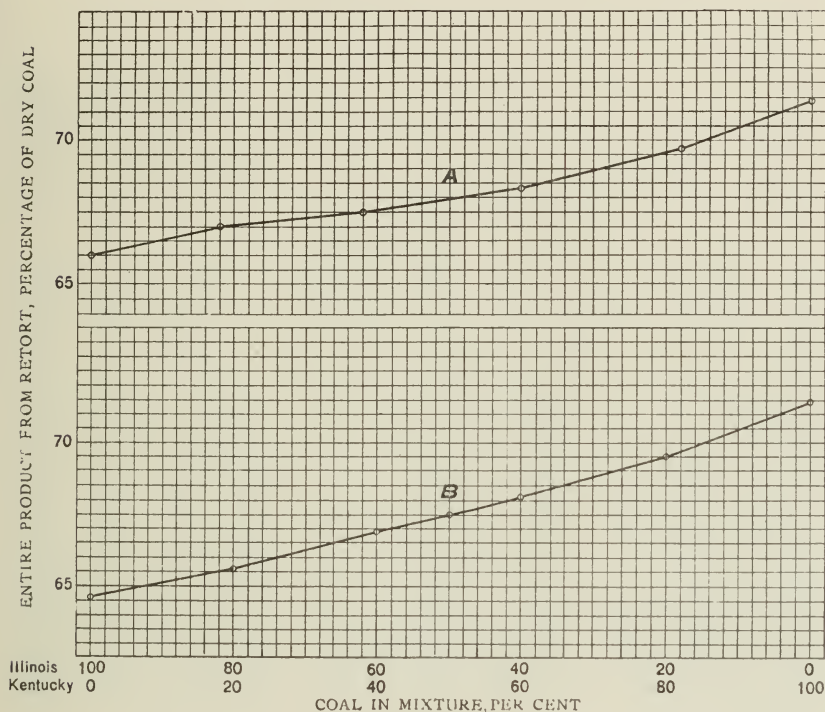


Fig. 1.—Yield of entire product (coke plus breeze) discharged from the retorts: A, Illinois coal from Franklin County; B, Illinois coal from Perry County.

YIELD OF COKE AND BREEZE

The term "coke" is frequently used in a general sense without a definite meaning. In this paper, coke is used to designate that part of the entire product discharged from the retorts that was the oversize of a one-half inch square-hole screen, and breeze is the undersize of a one-half inch square-hole screen. The entire product from the retort is coke plus breeze. This usage is somewhat arbitrary, but is rather widely accepted.

Table 3—Data from

Kind of coal	Weight of charge	Duration of charge	Temperature inside of retort	Yield of coke from dry coal	Yield of breeze from dry coal	Analyses of coal as charged				
						Moisture	Volatile matter	Fixed carbon	Ash	Sulphur
1	2	3	4	5	6	7	8	9	10	11
ILLINOIS COAL										
Perry County	^a 959	7.5	1874	60.8	5.7	9.18	34.35	49.12	7.35	.81
Perry County	876	7.5	1927	58.2	6.5	10.80	32.81	47.22	9.17	.66
80 per cent Perry Co.....	^d 951	7.5	1853	60.0	5.6	9.22	33.75	48.44	8.59	.68
60 per cent Perry Co.....	919	7.5	1902	61.2	5.7	7.48	34.63	50.18	7.71	.70
50 per cent Perry Co.....	902	7.75	1687	62.3	5.2	6.96	35.23	51.07	6.74	.80
40 per cent Perry Co.....	823	7.75	1811	64.6	3.6	5.06	36.64	52.42	5.88	.85
20 per cent Perry Co.....	967	8.75	1806	66.2	3.3	4.50	36.67	54.00	4.83	.76
Franklin County.....	964	7.00	1772	58.8	7.2	11.74	29.93	48.52	9.81	1.39
80 per cent Franklin Co. ^b 1048		7.5	1597	57.5	9.5	7.20	33.70	50.02	9.08	.91
60 per cent Franklin Co.	1021	7.5	1717	61.9	5.6	6.72	34.62	50.86	7.80	.95
40 per cent Franklin Co. ^d 890		7.5	1747	62.5	5.8	4.50	36.23	52.50	6.77	1.03
20 per cent Franklin Co. ^d 970		7.5	1780	65.6	4.1	4.87	35.88	53.71	5.54	.94
White County.....	^b 942	7.0	1852	61.0	4.4	7.20	35.70	47.51	9.59	3.49
KENTUCKY COAL										
Harlan County.....	898	7.5	1775	66.6	4.8	4.68	37.06	53.72	4.54	.93

^aSize of coal charged, 2-inch.^bSingle test.^cTemperature low from charge of fuel in the generators; charge not completely carbonized.^dTop of charge not completely carbonized.

the tests

Analyses of coke					Physical properties of coke							
Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Apparent specific gravity	True specific gravity	Coke substance	Shatter test		Softening temperature of ash	Softening interval of ash	Flowing interval of ash
								Over 2-inch screen	Under 2-inch screen			
12	13	14	15	16	17	18	19	20	21	22	23	24
Pct.	Pct.	Pct.	Pct.	Pct.			Pct.	Pct.	Pct.	Deg. F	Deg. F	Deg. F
1.46	2.69	83.26	12.59	.72	.88	1.88	47.	24.2	75.8	2278	137	198
2.40	3.06	81.0	13.54	.65	.88	1.85	48.	21.1	78.9	2364	80	122
2.45	3.69	81.42	12.44	.62	.88	1.85	48.	21.1	78.9	2351	131	151
2.14	2.84	83.16	11.86	.66	.89	1.82	49.	27.3	72.7	2356	265	127
2.04	3.75	83.79	10.42	.67	.87	1.79	49.	30.8	69.2	2326	150	94
.85	2.39	87.19	9.57	.66	.90	1.83	49.	24.4	75.6	2414	134	89
1.49	2.70	88.10	7.71	.60	.95	1.82	52.	22.3	77.7	2525	96	125
2.05	4.65	77.99	15.31	1.07	.89	1.85	48.	30.0	70.0	2185	139	218
.82	4.71	81.72	12.75	.92	.90	1.80	50.	26.0	74.0	2201	106	216
.82	4.20	83.77	11.21	.86	.89	1.85	48.	26.7	73.3	2292	108	174
.54	4.89	83.85	10.72	.88	.95	1.81	52.	27.0	73.0	2235	70	130
1.98	3.49	86.19	8.34	.84	.91	1.80	51.	31.0	69.0	2375	135	140
2.16	3.59	80.23	14.02	2.56	.84	1.85	45.	24.5	75.5	1983	36	362
1.86	2.97	88.20	6.97	.67	.91	1.82	50.	30.4	69.6	2456	74	103

Figures 1 and 2 show the yield of entire product from the retorts and the percentage of breeze from different mixtures of coal. The charges ranged from Illinois coal unmixed through different mixtures of Illinois and Kentucky coal to Kentucky coal unmixed. With Illinois coal alone, the entire product from the retorts averaged 65.5 per cent of the coal used, calculated on a basis of dry coke and breeze from dry coal; with Kentucky coal

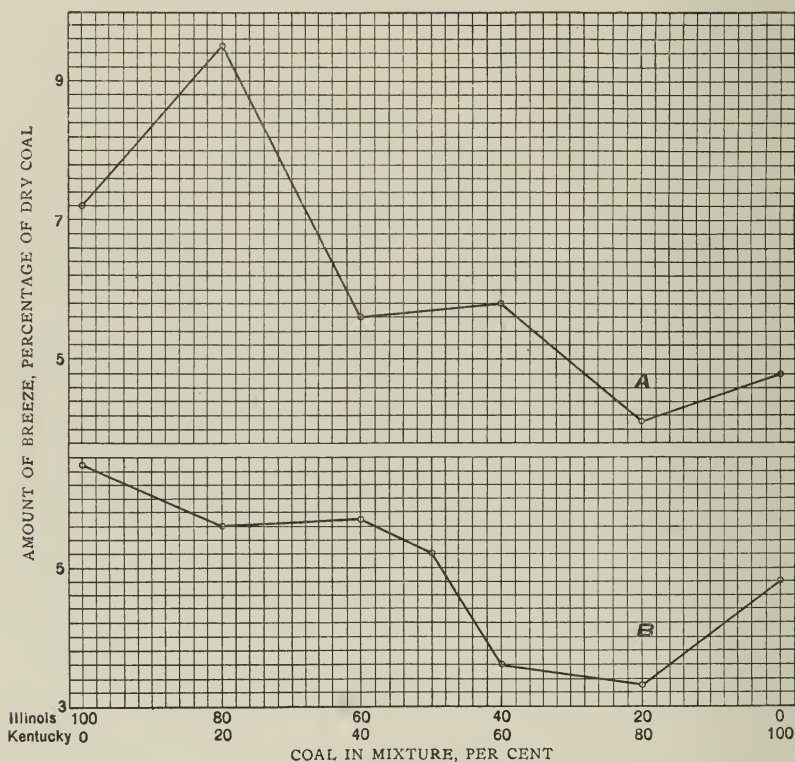


Fig. 2.—Percentages of breeze from different mixtures of coal: A, Illinois coal from Franklin County; B, Illinois coal from Perry County.

alone, the average yield on the same basis was 71.4 per cent. The yield of the entire product increased with decreasing percentages of Illinois coal; the lowest yield was from Illinois coal unmixed.

The amount of breeze was roughly proportional to the percentage of Illinois coal in the mixture; and increased with increasing percentages of Illinois coal. An exception to this rule was the amount of breeze from a mixture of 20 per cent Illinois

and 80 per cent Kentucky coal which was uniformly less than from Kentucky coal alone. Some of the duplicate tests showed considerable variation in the proportion of breeze, probably because the conditions of carbonization differed. High temperatures and long carbonization tend to produce strong hard coke. The same temperature and same period of carbonization will produce harder coke from a small charge than from a large charge. Inability to control these factors continually caused differences in the strength of the coke.

The Illinois coals tested showed little difference in the yield of entire retort product; Perry County coal gave a little less than Franklin County coal, but the latter produced slightly more breeze, so that the yield of merchantable coke was about the same from each coal. In the one test made, coal from White County gave about the same results as Perry County coal.

QUALITY OF COKE

The coke from mixtures was denser and harder, had a more uniform cell structure, and did not contain as much unfused material as coke from Illinois coal alone. A gradual improvement in the appearance of the coke was noticeable until the proportion of Illinois coal reached 60 per cent; above this point no improvement of appearance was evident. The percentages of coke substance as given in Table 3, indicate that coke from the mixtures was somewhat denser than coke from Illinois coal alone. It was also heavier and came from the retort in larger pieces. Mixing the coal lowered the ash content and raised its softening temperature, thus improving the coke as fuel.

The shatter test gave such variable results with coke from duplicate tests that the strength of the coke could not be judged from them. Temperature, time of carbonization, weight of charge, and like factors apparently affected the strength more than did mixing.

EFFECT OF SIZE OF COAL ON QUALITY OF COKE

To determine the effect of size of the coal on quality of the coke, tests were made with coal smaller than $\frac{1}{2}$ inch, but difficulties in handling and charging small sizes prevented definite results from being obtained. The writer believes that fine crushing will improve the strength and appearance of coke from Illinois coals. Examination of coke made from Illinois coal above 3-inch size shows that certain easily recognized layers apparently do not

coke but remain as unfused layers, along which the coke has a tendency to break. They are the dull black layers of the coal which do not possess the coking property. A stronger and more uniform coke probably would be obtained by crushing the coal and mixing the coking and non-coking layers.

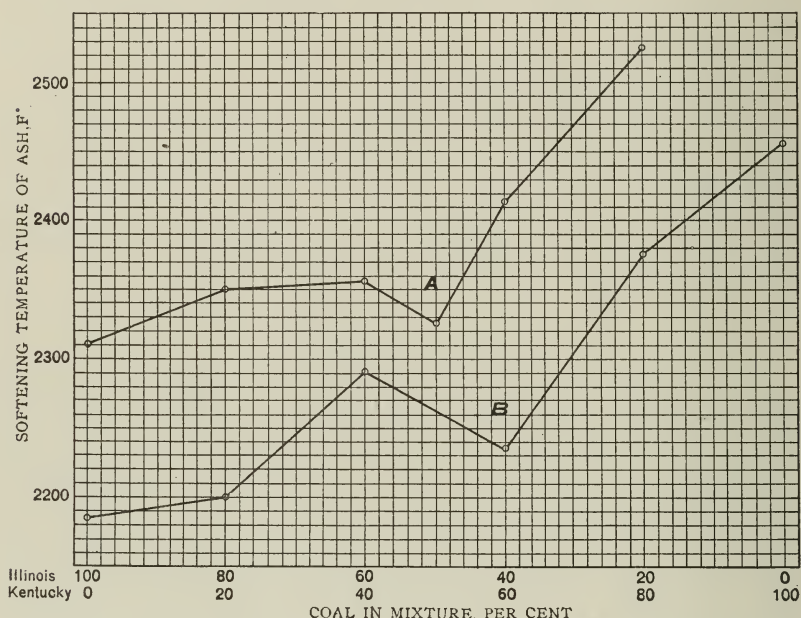


Fig. 3.—Effect of mixing Illinois and Kentucky coals on the softening temperature of the ash: A, Illinois coal from Perry County; B, Illinois coal from Franklin County.

ASH CONTENT OF COKE

The ash content of coke from Illinois coals tested was 12.5 to 15.3 per cent; whereas the ash content of the coke from Kentucky coal was about 7.0 per cent only. This suggests one advantage in mixing the coals. When equal parts of Perry County and Kentucky coal were mixed, the ash content of the coke was 10.4 per cent, a reduction of about one-quarter as compared with coke from Perry County coal unmixed. A high ash content not only reduces the heating value of coke but increases clinkering trouble.

CLINKERING TENDENCY OF ASH

The softening temperature, softening interval; and flowing interval of the ash (Table 3) give an idea of the tendency of the

coke to clinker when burned. Coke ash from the Illinois coals tested had softening temperatures of 1983° to 2364° F. Coke ash from the Kentucky coal had a softening temperature of 2456° F. For this reason coke from Illinois coal can be expected to show a greater tendency to form clinkers.

Figure 3 shows how the softening temperature of the ash is affected by mixing the coal. In all the tests the raising of the softening temperature of the ash was roughly proportional to the percentage of Kentucky coal added. Hence mixing the coals reduces the tendency of the coke to clinker, thus decreasing one of the disadvantages of using coke from Illinois coal.

YIELD OF GAS AND BY-PRODUCTS

With the equipment available for these tests the yield of gas and by-products could not be determined. However, results obtained by several gas companies that have experimented with Illinois coals, show that 4 to 4.5 cubic feet of gas, having a heating value of 585 to 600 B.t.u. can be obtained from each pound of coal. The yield of ammonia was 5 to 6 pounds and that of tar 10 to 12 gallons a ton of coal. The details of some of these tests are given in Bulletin 138 of the Bureau of Mines.¹

A larger yield of gas might be obtained, but the excess would be mostly hydrogen, which has a low heating value per cubic foot and would lower the quality of the gas below the standard fixed by law. It is, therefore, advisable to stop carbonization before all of the hydrogen has been driven off.

Illinois coals, probably because of a higher combined moisture content, yield more ammonia than most eastern coals. With good operating conditions a yield of 6 pounds of ammonia can be obtained per ton of Illinois coal coked.

The quality of the tar depends upon the amount of cracking in the volatile products, and this is controlled by the conditions of carbonization and the kind of retort. In general, tar from Illinois coal compares well with other tars produced by the same process.

HYDROGEN SULPHIDE IN THE GAS

The sulphur content of the Perry County coal was 0.66 per cent and of the Franklin County coal was 1.39 per cent. Assuming that one-half of the sulphur goes into the gas during the process of carbonization, the Perry County coal should yield gas hav-

¹Ovitz, F. K., Coking of Illinois coals: Bull. 138, Bureau of Mines, pp. 54-64, 1917.

ing about 600 grains of hydrogen sulphide per 100 cubic feet of unpurified gas, and the Franklin County coal should yield gas having a little more than twice that amount. Such quantities of hydrogen sulphide are not excessive. The coal from White County contained 3.49 per cent of sulphur and yielded gas that contained too much hydrogen sulphide to be handled efficiently by the ordinary purifying system.

An area of at least 75 square miles in Franklin and Williamson counties and a small area in Jackson County contain coal of a low enough sulphur content to permit its use for gas making without excessive trouble from hydrogen sulphide. There are probably other areas in Illinois that can produce coal with less than 1.5 per cent sulphur if special care is taken in mining and preparation.

IMPORTANCE OF GAS YIELD

The gas yield from Illinois coal is about 20 to 25 per cent less than that obtained from eastern gas coals. This means that about 20 per cent more coal needs to be carbonized, the labor cost will be larger, and the retort capacity will have to be greater for the same amount of gas. Coal-gas benches are usually worked to capacity at all times, and it does not seem possible to increase the charge or decrease the period of carbonization enough to make up for the difference in capacity occasioned by the use of Illinois coal. For example, if a retort carbonizes 400 pounds of coal yielding 5 cubic feet per pound in 4 hours, it would not be possible to increase the charge or decrease the coking period enough to make the same amount of gas from a coal yielding 4 cubic feet. Additional retorts would be required, and the consumption of bench fuel would be larger.

The bench fuel is reported customarily as the number of pounds of fuel used for heating the retorts per unit of coal carbonized. This method fails to take into account the gas yield from the coal. As the superintendent is concerned with the cost of gas in the holder, the bench fuel used per unit of gas would seem to be a better standard, as it allows the proportionate cost of fuel for carbonizing coals with different gas yields to be obtained at a glance.

There may be gas plants in which the capacity of the retorts could be increased enough to supply the required gas by using coal yielding 4 cubic feet of gas a pound. Where such conditions exist it is advisable to inquire into the relative prices of Illinois and other gas coals, as the difference in price may more than off-

set the lower gas yield from Illinois coal. Even when the retort capacity is not sufficient to permit the use of Illinois coal alone, it is sometimes possible to use one-third to one-half Illinois coal and in this way decrease the cost of gas in the holder.

ADVANTAGE OF MIXING THE COALS

The coals may be charged separately into individual retorts or may be mixed before charging. The last method is preferable as it allows more uniform operation and gives better coke. When the coals are mixed, the difficulties of regulating conditions to suit two different coals are overcome.

Illinois coal requires more heat to carbonize properly than many other gas coals, and consequently either the temperature of the retort should be higher or a longer period of carbonization should be allowed. When part of the retorts are charged with Illinois and part with another coal, there is difficulty in regulating conditions to suit both coals. For example, if the temperature is adjusted to carbonize the Kentucky coal in six hours, the Illinois coal will be unfinished at the end of that time. If carbonization is stopped the gas yield not only will be low, but the coke will be of poor quality. On the other hand, to permit the Illinois coal to remain longer in the retorts than the Kentucky coal interferes with the operating schedule.

METHOD OF MIXING THE COALS

Unlike by-product coke oven practice, in retort gas manufacturing it has not been customary to mix coals before charging; consequently at gas plants there is usually no mixing equipment. In small plants where the retorts are hand fired, a coal crusher is almost the only equipment required. The coals can be mixed when they are shoveled into the coal car which hauls them to the retorts, by taking alternate shovelfuls of each kind. The coals should be stored so that each kind can be loaded into the car without changing its position. They are re-handled enough to mix them when they are charged into the retorts. All the coal should be crushed to a maximum size of 2 inches, so that non-fusing layers in Illinois coal will be mixed with the fusing.

In plants where the coal is handled and the charging is done by machinery, extra equipment usually will be required. In some cases the equipment in use might be adapted to do the work by slight changes. No general method can be given, as most plants are arranged differently, and mixing is a separate problem at

each. The mixing should be done preferably before the coals are put into the charging bins, as merely putting two kinds of coal into the larry would not mix them. A good time for mixing is during crushing. This could be done by having an unloading hopper for each kind of coal and a conveyor from each hopper to the crusher. The desired amounts of each coal for the mixture could then be supplied to the crusher, and the coals would mix while being crushed and conveyed to the charging bins.

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